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PRODUCTION OF POTATO STARCH WITH LOW WASTE

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Abstract

The use of fine grinding and air classification of dehydrated potatoes with sieving and minimum washing to produce potato starch is described. A substantial reduction in the amount of waste water over that required by conventional wet milling procedures was obtained. The procedure proposed would reduce wastes by 90%.

Introduction

This paper reports on investigations of potato starch production employing air classification technology, and on refinement of the starch fraction by carefully controlled washing. Utilization of the small amount of waste water was also considered.

Potato starch is traditionally produced by wet-milling, which requires large amounts of water to separate proteins, pulp, and other materials from the product. Olson (1) reported that, in a plant which utilizes 250 tons/day, the waste water was 800 gals/ton, excluding water for washing potatoes. In a modern plant in Europe, Caransa (2), with the newest processing equipment, predicted needing 792 gals/metric ton. Disposal of this waste water becomes difficult since Federal and State laws prohibit disposal in water courses, and disposal through municipal sewage plants would be expensive. Due to the low concentration of solids in waste water (1% according to Heisler (3), Olson (1), and deKoe (4)), little had been done towards recovery of components until the recent work of Heisler et al (3).

Since the mid-1950's, air-classifiers have become important devices for separation of flour by particle size and density (Graham (5)). The fine grinders and classifiers described by Behrens (6) effectively separated flour into fractions having varying protein contents. Gracza (7) defined this change in protein content of flour fractions as degree of protein shift. Peplinski et al (8) demonstrated that physical characteristics of wheat classes and variety influence this protein shift. Kent (9) showed that changes in moisture content of wheat or flour also appreciably altered the effectiveness of the protein shift. The number of fractions obtained was dependent upon the complexity of the flow employed in making the separations.

If finely ground, dehydrated potatoes have properties similar to those of wheat flour, perhaps the product could be separated into a "protein

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fraction" (suitable for animal feed) and a "starch fraction." If the starch fraction thus produced was not of commmercial quality, it could be washed under careful conditions to minimize the amount of water used.

The concentration of solids in this wash water might be high enough that drying would be economical, thereby eliminating the waste problem; or recovery of valuable components by such processes as ion exchange could make production of potato starch more economical. Even if neither alternative was attractive, the amount of waste for disposal would be greatly reduced over present practices.

Materials and Methods

The test potatoes were from sound, washed, random lots of various varieties which had been stored at 10-19 C. They were cut, dipped in 0.1% $NaHSO_3$ solution and dried as described in each experiment.

The dried samples were ground on an Alpine Pin Mill, Type 160[3], Alpine American Corporation, Saxonville, Massachusetts.

Samples were classified on a Midroplex Spiral Classifier, Type 132MP[3], Alpine American Corporation, Saxonville, Massachusetts.

Total sugars. Determined by the Anthrone Method of Ashwell et al (10).

Reducing sugars. Determined by a modified Nelson-Somogyi Method (11).

Starch. Sample was refluxed for 2.5 hours in 10% HCl followed by neutralization and by determination of reducing sugars, from which values for the previously determined total sugars were subtracted. A sample of pure potato starch similarly treated was used as a standard.

Protein. AOAC 9th Edition. Protein as measured by micro-Kjeldahl nitrogen x 6.25 was selected as a criterion of cleanliness; it being less soluble than sugars, amino acids, organic acids, etc.

Moisture. Determined by overnight drying in a vacuum oven at 32 C.

Agtron color. Determined on an Agtron M-500 00/0-97/100[3], Magnuson Engineers, Inc., San Jose, California.

Gelatinization. The Brabender Amylograph[3] was employed in studying the gelatinization properties of the different potato starches. A 20g. sample of starch (dry basis) in 450 ml. distilled water was used for the determination. The temperature on the amylograph was programmed from 25-95 C., increasing at the rate of 1½° per minute. The temperature was then held at 95 C for 15 minutes and was followed by controlled cooling to 50 C. The initial temperature of gelatinization, peak height, 15-minute-hold height, and 50 C peak height were recorded.

Results and Discussion

Fine granding and air classification.

An initial experiment was conducted by using potatoes which had been dried at 85 C and course ground on a pin mill at 9,000 rpm. The

[3]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

ground potatoes were then classified and the course fraction or "starch fraction" was reground in the pin mill at 19,000 rpm and classified. This initial study showed that a significant shift in protein content had been obtained by such a technique, and that, similar to wheat flour, potatoes could be air classified after fine grinding (Table 1).

The second experiment was conducted to obtain a protein profile-air classification fractionation curve. Thee potatoes were dried at 85 C and then run in the pin mill at 19,000 rpm. After each classification, the starch fraction was recycled through the classifier with minor changes of equipment settings.

Table 2 shows that potatoes are affected somewhat as is wheat flour (Pfeifer and Griffin (13). There is a "protein fraction" that can easily be separated from a "starch fraction" and, as with wheat flour, continual reclassification of the starch fraction improves separation only up to a point. It appears (Table 1) that it would be impossible to produce a starch fraction of less than 4% residual protein by air classification alone.

Visual inspection of the fifth cycle starch fraction showed it to be enroched in coarse brown particles. A simple screening test indicated that most of these brown particles were retained on a 125-micron screen.

A third experiment was conducted to determine the effect of separating the ground potatoes into two fractions, first by sieving and then by additional fine grinding of the coarse, starch fraction after air classification. For this, potatoes were dried at 60 C, ground, and then pin-milled at 14,000 rpm. Sieving over a 125-micron screen separated the ground material into two fractions. Material remaining on the screen was principally coarse, brown peel fragments. That which passed through the screen was air classified. The starch fraction of the first cycle was reground at 19,000 rpm and again classified.

Sieving to remove brown peel and fibre fragments before classification significantly lowered the residual protein in the starch fraction as shown in Table 3.

A sample of blanched, dehydrated diced potatoes was obtained from a local source for a fourth experiment to determine if blanching would affect the protein-shifting potential. The data indicated that even cooked potatoes exhibit some protein shifting when fine ground and classified.

A fifth experiment was conducted to determine the effect moisture content might have on air classification of potatoes and on protein shift. Potatoes were dried at 60 C and run through the pin mill at 14,000 rpm. Material passing through 125-micron screening was exposed as a thin layer to high humidity overnight. This "high moisture" material was classified, the "first cycle starch fraction" being reground at 19,000 rpm and again classified. (Table 4)

Moisture as high as 11% does not materially affect air classification of finely ground potatoes.

A sixth experiment was performed to determine the effect of drying temperature upon air classification of the potatoes. About one-half of the potatoes were dried at 82 C, the rest being dried at 121 C; all were run through the pin mill at 14,000 rpm. Material passing through a 149-micron screen was exposed to high humidity and classified. The starch fraction

TABLE 1.—*Results from initial study of air-classified whole potatoes.*

Sample	Grind RPM	Classifier settings		Classified fraction	% of product	Protein content	Moisture content
		Feed gate	Fin setting °			%	%
Control		....	....	....	100	8.5	4.7
1st cycle	9,000	15	10	Protein	8.8	15.2	4.3
				Starch	91.2	6.8	3.9
2nd cycle	19,000	15	10	Protein	4.2	22.4	2.7
				Starch	95.8	6.3	4.9

TABLE 2.—*Effect of reclassifying starch fraction.*

Cycle	Classifier settings		Classified fraction	Weight	Protein content	Starch content	Sugar content	Moisure content	Others
	Feed gate	Fin setting		Lbs.	%	%	%	%	%
0	....	....	Control	50	7.9	79.6	.8	1.3	10.4
1	15	10	Protein	2.3	30.0	30.6	1.7	1.3	36.4
			Starch	46.3	5.8	83.7	1.0	1.7	17.8
2	15	15	Protein	1.7	18.1	61.8	1.3	2.2	16.6
			Starch	44.0	5.4	82.9	.9	1.3	9.5
3	15	25	Protein	6.1	8.2	76.3	1.0	1.2	13.3
			Starch	37.3	5.3	83.6	.9	2.0	8.2
4	15	35	Protein	21.1	5.6	76.1	.8	1.7	15.8
			Starch	15.1	5.0	82.9	.9	2.8	8.4
5	10	38	Protein	7.3	5.3	81.9	.9	2.2	9.7
			Starch	7.6	5.2	80.1	.7	1.7	12.3

was reground at 19,000 rpm and again classified. The feed rate to the classifier was varied in the second cycle of each run. (Table 5)

The initial drying temperature does not affect classification. The darker color as reflected by Agtron color (Table 4 and Table 5) indicates some heat damage; as one would expect. The potatoes were hard and vitreous at 121 C, and did not grind easily; thus the preliminary screening was done on a 149-micron screen.

TABLE 3.—*Effect of preliminary sieving before classification.*

Cycle	Grind RPM	Classifier settings		Classified fraction	Weight	Protein content	Starch content	Sugar content	Moisture content	Other
		Feed gate	Fin setting °		Lbs.	%	%	%	%	%
0	14,000	....	....	+125 micron	1.3	8.7	75.7	1.2	3.3	11.1
				—125 micron	25.8	6.9	80.1	0.7	2.5	9.8
1	14,000	15	25	Protein	2.8	18.5	44.0	1.3	3.6	32.6
				Starch	22.8	4.9	82.7	0.5	3.1	8.8
2	19,000	15	25	Protein	3.3	11.6	71.6	1.3	4.3	11.2
				Starch	18.3	4.0	86.1	0.4	2.7	6.8

TABLE 4.—*Effect of high moisture on air classification of potatoes.*

Cycle	Grind RPM	Classifier settings		Classified product	Weight	Protein content	Moisture content	Agtron color
		Feed gate	Fin setting °		Lbs.	%	%	
0	14,000	....	....	Starting	24.0	8.0	11.4	82.5
1	14,000	15	25	Protein	2.5	17.1	7.2	81.7
				Starch	21.0	4.7	10.9	86.7
2	19,000	15	25	Protein	2.0	11.9	6.9	84.8
				Starch	17.3	4.5	8.2	90.8

Purification of starch fractionation.

Previous experiments showed that the starch fraction should be washed in order to make a commercially acceptable product with less than 1% protein. Fig. 1 outlines a typical procedure in the reusing of wash water in a counter-current fashion.

Initial mixing required 3 parts of liquid to 1 part of starch fraction, while subsequent steps required 2 parts of liquid. Material in the brown starch tank contained white starch and pulp as well as dissolved solids. This "brown starch" liquid was screened in such a fashion that the white starch and half the liquid was returned to the system, the pulp and remaining liquid being withdrawn. The amounts of protein in the washed starch and solids in the wash liquid were determined at each step. Typical data are presented in Table 6.

In another experiment the final wash water had a total solids concentration of 10.85%. The analysis of these solids is presented in Table 7.

TABLE 5.—*Effect of drying at 82 C and 121 C on classification of potatoes.*

Cycle	Grind RPM	Classifier settings		Classified product	Weight	Protein content	Moisture content	Agtron color
		Feed gate	Fin setting °		Lbs.	%	%	
				DRIED AT 82 C.				
0	14,000	....	....	Starting	26.3	6.8	6.6	77.0
1	14,000	15	25	Protein	4.5	14.2	5.1	79.5
				Starch	21.5	5.1	7.7	79.8
2	19,000	10	25	Protein	2.3	12.7	4.3	79.8
				Starch	18.3	4.4	6.1	84.9
				DRIED AT 121 C.				
0	14,000	....	....	Starting	25.0	6.6	4.6	64.9
1	14,000	15	25	Protein	3.0	14.1	3.4	70.2
				Starch	21.8	5.7	4.8	64.6
2	19,000	20	25	Protein	3.8	10.7	3.6	75.9
				Starch	17.3	5.0	4.1	72.8

TABLE 6.—*Typical analysis of protein in washed starch and solids in wash water in countercurrent washing.*

	Protein	Solids in washwater
	%	%
4th washing	.99	.2
3rd washing	1.07	1.0
2nd washing	1.48	2.9
1st washing	1.98	9.1
Initial	4.5	

TABLE 7.—*Analysis of solids in final wash water.*

Total solids	10.85%
Protein (Kjeldahl X 6.25)	28.5
Protein (Biuret reagent)	(4.6)
Free amino compounds (as asparagine using Stein-Moore reagent)	(20.4)
Amino compounds automatic amino analyser	(18.8)
Total reducing sugars	12.4
Total organic acid	35.4
Potassium (flame photometer)	17.7

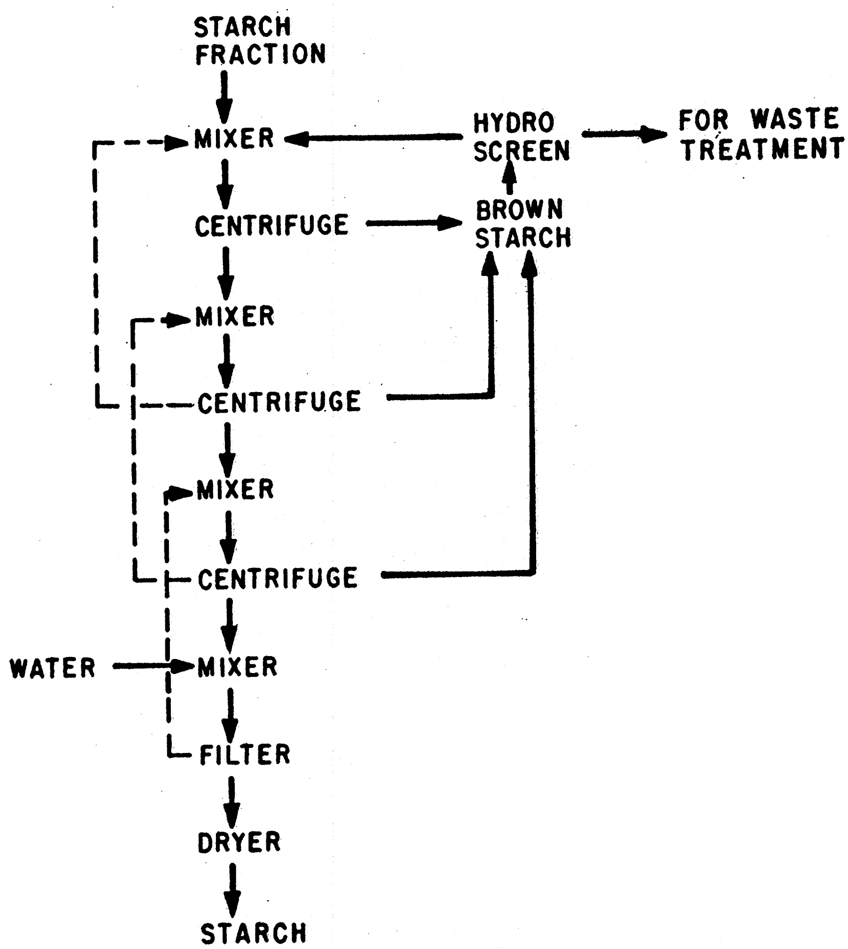

FIG. 1.—Diagram of countercurrent washing procedure.

The starch fractions of material dried at 82 C and 121 C were similarly washed (Table 5). That from the higher drying temperature contained a partially gelatinized material which required 5 volumes of water to make into a workable slurry. The gelatinous material was removed with the brown starch.

Brabender amylograph curves were calculated to determine if the starch had been heat-damaged and are shown in Fig. 2. The temperature of initial gelatinization was essentially the same for all of the starches except the commercial. This starch had a slightly higher initial temperature of gelatinization. From an examination of Fig. 2 it can also be observed that the commercial starch granules swell more readily than do those of the other starches. The highest peak was obtained from starch

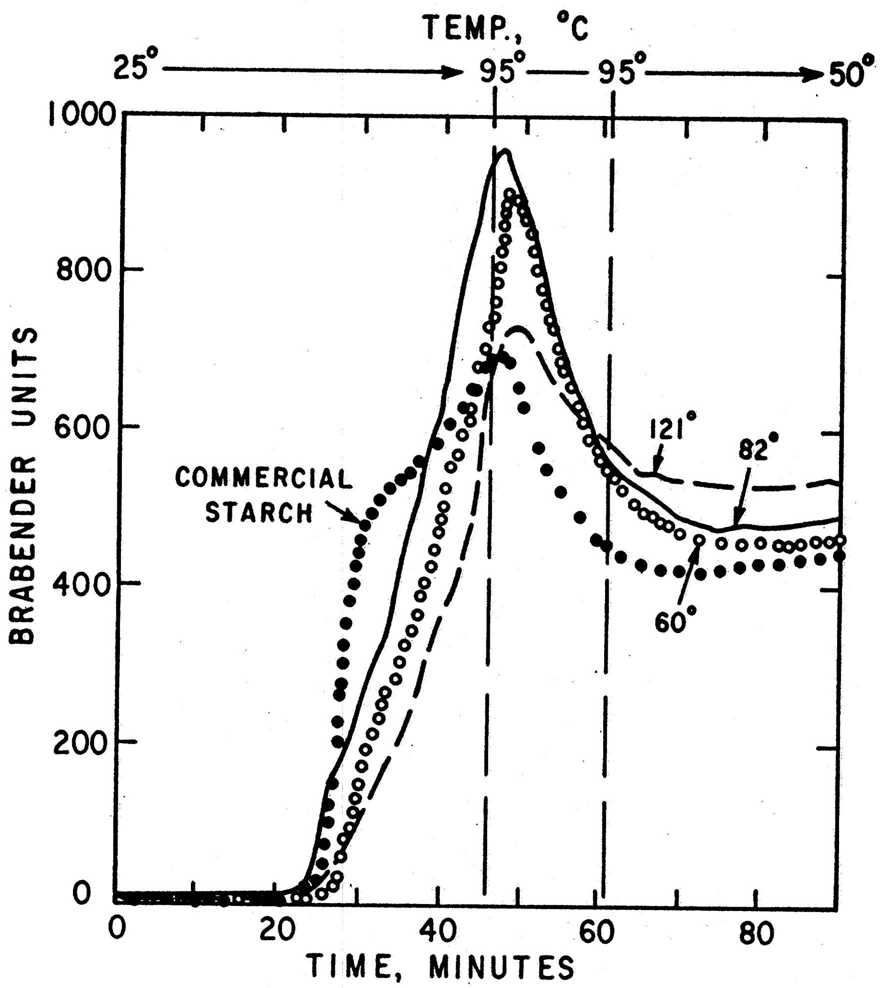

FIG. 2.—Braebender curves for washed starch from 60 C, 82 C, and 121 C dehydration.

dried at 82 C and the lowest point was obtained from the Grafton commercial starch. Variations in peak height amongst the different starches were observed. A definite breakdown was observed for all of the starches during the 95 C hold period although the breakdown was not the same in all cases. Likewise, the height at 50 C varied somewhat for the different starches.

An experiment was designed to maximize yields of starch and to determine the efficiency of a process employing fine grinding, air classification, sieving, and washing. Data obtained from previous experiments indicated that, with the proper combination of the various treatments, it was possible to obtain an acceptable potato starch that would require considerably less water for removal of protein and other solids.

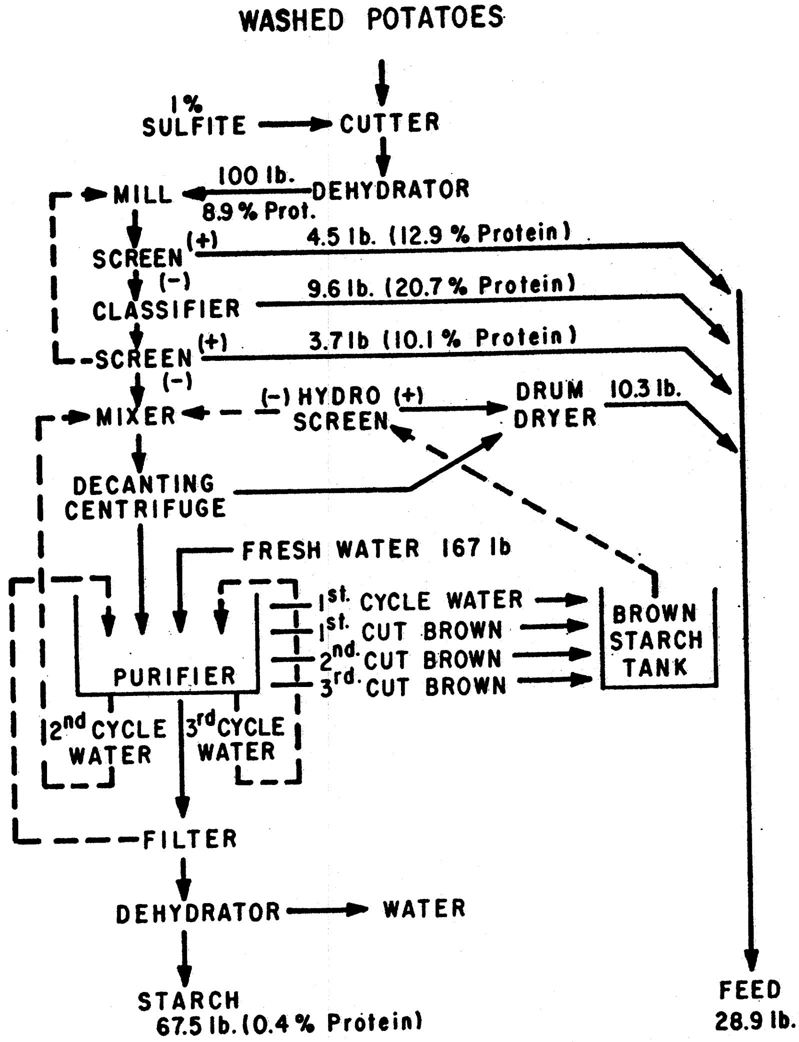

FIG. 3.—Efficiency of proposed procedure for potato starch without waste. (air-dry basis)

The potatoes were dehydrated at 60 C and put through the pin mill at 19,000 rpm. Screening through an 88-micron screen best removed brown particles. Material passing through the 88-micron screen was classified and the starch fraction reclassified until 10-15% of the starch was removed as protein fraction.

Removal of some brown particles from the starch fraction was sieved with a 53-micron screen and 53/44-micron screening removed a small amount of inadequately ground particles. Normally, this 53/44 fraction would be reclaimed by recycling through the mill. The 44-micron material was used for starch washing steps.

The final, screened starch fraction was then washed by the counter-current procedure of Fig. 1, including the recovery of white starch in the brown starch fraction. The recovered starch was dried and weighed. This experiment is summarized in Fig. 3.

The final wash water of 10-11% solids represents a tenfold concentration over normal waste effluent of a conventional wet-milling potato starch plant, and thus a 90% reduction in volume of effluent. Such a waste effluent could be drum-dried. deKoe (4), working with 1% solids effluent from a European starch plant, recommended spray drying after pre-concentration. Effluent of 10-11% solids should further enhance his suggestion.

Strolle, et al (14) discussed de-proteinization of simulated starch waste prior to ion exchange and showed that increasing total solids from 1.5% to 2.8% significantly increased the efficiency of the protein removal necessary for ion-exchange. Increasing solids to 10-11% should further increase efficiency of protein removal.

Conclusion

On a laboratory scale, the process of drying, fine grinding, air classification, and washing can be fairly efficient. The unit processes are straightforward and use in a larger operation should be feasible.

Use of the drum dryer for wash-water drying would not involve a waste effluent. Alternately, the liquid could be added to previously separated protein fraction and redried in a pulp dryer. The animal feed fraction obtained from the process would have a protein content of 15-20% compared to the 6-8% protein in the dried potato pulp from a conventional potato starch plant.

If recovery of valuable by-products by means of ion-exchange appears to be attractive, the amount of waste effluent for disposal would be only a fraction of that from a wet-grinding starch plant. Even without drying or ion-exchange, the volume of waste is only 10% and the quantity of solids only 40% that of a conventional plant.

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